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ABSTRACT

Two instructional strategies stress effective reading during science instruction at the middle grade level. One uses print material for enrichment, while the second uses print as the primary instructional medium. Teachers can help students get ready to read in content areas by stimulating their interest in a variety of ways: capitalizing on chance occurrences, discrepant events, exotic demonstrations, and so on. Outlining student questions on the blackboard also provides purpose and focus for subsequent reading. When reading replaces the laboratory phase of an inquiry lesson, study guides reflecting instructional objectives provide the structure needed to increase student comprehension. Postreading discussion of the questions outlined earlier increases student comprehension and minimizes the negative effects of poor reading. Since teaching science solely through reading misleads the students as to the nature of the discipline, reading should be used in concert with activity oriented inquiry programs. The nature of science texts does, however, require that students have the ability to analyze cause and effect statements, directions, and Latin and Greek root words. Because of the close relation of mathematics to science, students must also be able to decode mathematics and word problems, graphic materials, and symbolic statements. (JL)

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Helping Students Read Middle Grade Science Materials

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Despite pressure from scientists, curriculum experts, and publishers to make the science curriculum activity-based rather than textbook-based, sales reports indicate that science curricula are dominated by textbook programs. Although the writers support activity-based programs, teachers must work with the resources at hand - mainly texts. This paper, therefore, explores teaching strategies, specific skills, and problems unique to the middle grade science program.

Teaching Strategy

The organization of science instruction utilizing print materials should attempt to reflect effective reading as well as science instruction. Two instructional sequences have potential for improving reading while maintaining the unique nature and positive attributes of inquiry science instruction. The following strategies illustrate: 1) an approach which utilizes print material for enrichment, and 2) an approach which utilizes print as the primary instructional media:

(1) Pre-lab ⟶ Lab ⟶ Post-lab ⟶ Reading ⟶ Post-reading Discussion

or

(2) Introduction ⟶ Reading ⟶ Post-reading Discussion

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The first strategy attempts to provide concrete hands-on experiences to enrich the reader's background and thus improve the meaningfulness of the print to be read. This strategy systematically considers student motivation, problem focus, concrete experience, closure, introduction of the reading, reading, and closure of the reading.

The second strategy attempts to substitute an enlarged introduction for the inquiry phase (pre-lab, lab, post-lab) of the first strategy. The introduction should consider similar purposes as the activity-oriented pre-lab (Yore, 1976):

Pre-Lab	Introduction to Reading
1. Establish set (motivation and problem focus).	1. Establish set.
2. Delineation of the problem.	2. Purpose for reading or delineate problem.
3. Design and plan the problem investigation.	3. Procedure for reading or plan approach.
4. Develop prerequisite lab skills.	4. Develop prerequisite reading skills.
5. Consider safety precautions.	

A one-to-one correspondence does not occur between pre-lab and introduction as some purposes, like safety, are unique while reading skills and lab skills are interchanged.

Establishing Set

The importance of establishing a mental set for the enhancement of learning has been stressed in previous publications. Vacca (1977) stated,"The goal of readiness to read in content areas presumes that students will be mentally and psychologically prepared to begin a reading assignment - in a state of mind which will promote learning." Fredericks (1968) suggested:

> Pre-learning experience can be used to advantage in readiness if experiences: 1) lead to a concept, 2) are relevant to the concept, and 3) provide a direction in learning the concept.

Teachers can help to create interest by capitalizing on chance occurrences, discrepant events, exotic demonstrations, jokes and games appropriate to the learners and topic under consideration (Yore, 1976). The motivation device should reveal unique problems that can be solved by reading the textual materials as well as providing background and embryonic insight into the phenomena. Newspaper articles on forthcoming meteorite showers might be appropriate stimuli for reading about astronomy. Optical illusions can effectively introduce readings on the eye; an ammonium dichromate reaction may stir curiosity about volcanoes; while British Columbia cartoons are appropriate to a wide variety of science topics (Yore, 1975).

Developing Purpose

Outlining student-initiated questions on the chalkboard (see Figure 1)

will help reinforce the major ideas to be discovered, thus providing purpose and focus for the subsequent reading.

Figure I

Group Prediction Activity

Topic: Insects

What We Know Now	What We Want to Learn
Three body parts Spiders aren't; flies and mosquitoes are small size, fly	Names of body parts, are all insects parts? Do all insects fly?

Figure I represents the end product of a teacher who wished children to learn something about insects. The topic is set on the chalkboard and the children asked if they know anything about insects. The teacher should record in short sentences or key phrases the information provided by the children. When such information has been set down, the teacher may formulate questions that are: 1) based on the information provided by the children and 2) are answered in the material to be read. For example, if a child has provided the fact that insects have three parts to their bodies, then the teacher, knowing that the passage to be read contained this information, might ask, "Does anyone know the names of the three parts?" If this information is provided, it is set

down under the "What We Know Now" column. If no one knows, it is set down as a question under the "What We Want to Learn" column.

When recording the information and questions, it is best to organize them in the same order as they will be encountered in the text. Science texts tend to be densely packed with information which makes these texts difficult to read and forces a slow rate of reading. To avoid overburdening students, it may be necessary to divide reading tasks into small pieces. When using the student questioning technique explained above, students may be asked to read in order to answer only one or two questions rather than answering all of the questions at once or individual questions might be assigned to different groups of students.

Reading

The reading task replaces the laboratory phase of an inquiry lesson. Reading is the process by which the students collect data from which they will later formulate solutions to the focus problems. As is the case when observing and measuring in inquiry laboratories, many students leave the reading task with unsynthesized bits of data. This occurs to a lesser degree in well-organized and readable textbooks. Study guides reflecting the instructional objectives can provide the required structure to increase comprehension of the science materials and avoid the problems inherent in inappropriately organized materials. The following example (see Figure 2) illustrates the stepwise development of producing a study guide for a specific science passage.

Introducing Science Concepts in the Laboratory, (Schmid, 1973).

Figure 2

Production of a Study Guide

Step 1: Reviewing the Printed Material

Original Text: "A material that is identical throughout and always the same as any other sample of the material is called a substance. For example, pure water is a substance because no matter where it is found, it is like all other water. It is the same throughout because all its particles are the same. A solution of table salt, for example, is not a substance because it contains several kinds of particles mixed together."

Step 2: Teacher Appraisal

Comment: Text cannot be read independently because substance is a new term. The examples provided in the text are too limited to illustrate this concept. Students need multiple positive and negative examples.

Step 3: Production of Supplementary Activity

These are substances -- pure water, oxygen, gold, sulfuric acid.
None of these are substances -- salt water, air, iron ore, strawberry jam.
Circle the substances from the items below.
mile wood carbon dioxide iron gold ore citric acid
Now read pages 38-40 in your science texts to get a better understanding of substances.

Introduction Vocabulary: Example Carbohydrates (alone, with context, with demonstration)

The post-reading discussion of the questions developed earlier to provide purpose should attempt to get students to share, integrate, synthesize, and apply insights obtained from the written materials. Organizing teacher-directed questions to get students to recall, translate, and synthesize the knowledge fragments will help students to comprehend the science concepts and minimize the negative effects of poor reading. Special consideration may be needed so that the children's inability to read does not prevent them from doing the necessary thinking (Durrell, 1975). The logically-structured oral discussion will allow the less able readers to experience a developmental logic of science and share insights of their peers. Closing application level questions will help associate the newly-acquired knowledge with realistic uses and will improve retrieval of the knowledge at a later time. Applications should explore situations which are not defined in the textual materials, but which are related to the students' reality, such as current movies, sports or toys.

The development of a bibliography of books, articles, pamphlets, and student reports (Harp, 1977) related to the topic and with a wide range of readability can provide an open-ended component for interested students by providing supplemental readings.

Teaching science exclusively by the use of reading is a questionable

practice, as it creates an image of science which is faulty -- namely, that science is strictly a noun rather than a verb, a static historical record of others' discoveries rather than an ongoing process of human creativity. Books and reading are part of the organization of science knowledge, but should be used in concert with the activity-oriented inquiry programs.

An analysis of textual science materials reveals that certain specific reading and reading-related skills are required for reading a wide variety of science texts and thus deserve special attention. Cassidy (1977) in a Right to Read funded project, Content Area Reading Enrichment (CARE), found that reading science material required the ability to analyze: 1) cause-and-effect statements, 2) directions (step-by-step list and narrative forms), and 3) Latin and Greek root words.

Cause-Effect Statements

The nature of science dictates that science textual materials will include a high concentration of cause-and-effect statements containing logical connectives. Cause-and-effect statements may involve the linking of two propositions or sentences by a connective. Logical linkage is accomplished in a variety of ways, such as prepositional phrases, adjectives, explicit indicators, coordinators, and adverbials. Several classes of advervials exist based on their pupose, such as 1) additive adjunct (too) 2) restrictive adjunct (exactly), and 3) disjunct (perhaps) or 4) conjunct (hence). Table I provides a list of very difficult connectives (Gardner, Schafe, Myint-Thein, and Watterson, 1976). Specific instruction with connective and cause-and-

effect sentences will be worthwhile. A simple example of a cause-and-effect activity is provided in Figure 3.

Table I

Very Difficult Connectives

apparently	in general
as much as	in practice
at the same time	in that
by way of	in turn
clearly	moreover
conversely	notice that
essentially	respectively
further	say
furthermore	similarly
hence	since
in addition	so also
in contrast	still
indeed	that is

Figure 3

Cause-and-effect Example

"There are some people who will tell you to remove food from cans immediately after opening them or else the reaction among the food, can, and air will make the food poisonous. The premise is false. Food in an opened can will not become poisonous any faster than it would if removed, because it is the airborne bacteria that causes food to spoil, not the metal of the container. To prevent food left in a can from spoiling, cover the can." (Richard A. Boning, Specific Skill Series, Drawing Conclusions, Book G, Barnell Loft, Ltd. unpaged)

1. What causes food to spoil?
2. Covering a tin can after it has been opened prevents the formation of poison because _____

_____

Note that number 1. evaluates whether students are alert to the use of "because" as a signal for a cause-effect relationship. If they do not recognize this signal, simpler examples will be needed, e.g. We didn't go on a picnic because it rained. Number 2. tests students' ability to provide the effect when they have been provided with the cause and signal word.

Directions

One of the goals of a science program is to have students acquire science content, understand scientific processes, and become interested in scientific inquiry by independently examining, organizing, and analyzing data. In order to complete independent activities successfully students must be able to read and follow directions. Pikulski and Jones (1977) have identified five factors which influence readability of directions. Easy-to-read directions are characterized by:1) familiar sentence structures, 2) familiar vocabulary, 3) illustrations, 4) careful sequencing, and 5) readable print.

Clear directions contain familiar sentence patterns. The easiest sentence pattern to understand is subject-verb-object. Directions should use simple declarative sentences whenever possible. Pronouns should be minimized, since pronouns may be difficult to interpret as children have difficulty identifying and remembering pronoun referents.

Vocabulary is the second factor influencing the readability of instructions. Concept words, such as chemical, magnetic or corpuscle, may need to be introduced by the teacher before students are expected to complete independent activities (experiments or readings). Terms such as estimate or determine may need to be replaced by the more common student vernacular, i.e., guess or find out. Difficult vocabulary turns student-centered explorations into teacher-dependent activities.

Illustrations also have an important role in aiding students to understand instruction. When pictures illustrate difficult concepts, the reading difficulty is reduced. A complex operation may sometimes be illustrated by a picture sequence which makes the sequence much easier to follow. Students frequently forget to look at illustrations, so a simple statement like, "Look at the picture," is helpful in the directions at the appropriate place.

The fourth factor is the sequence of directions. Numbering each step is advisable. Give instructions in the order they should be executed; for example, it is better to say, "Answer the questions. Then draw a diagram." than "Draw the diagram when you have finished the questions."

The last factor is typography. Small and/or crowded print is much more difficult to read than large, well-spaced print. Do not be afraid to leave generous margins. Color-coding and underlining add emphasis when used sparingly.

Root Words

The importance of Latin and Greek combining forms (prefixes, suffixes, and root words) needs to be explicitly shared with students. Words with frequently-used prefixes like iso-, meso-, centi-, poly-, tri-, a-; and suffixes like -ship, -ial, ization; morphi, mer, chomatic, therme and scales should be included in vocabulary lists and word games. A quick search of

science and mathematics books' glossaries will pinpoint the appropriate suffixes and prefixes, or Piercey (1976) provides an excellent list of combining forms for science.

Knight and Hargis (1977) suggested specific instructions in decoding word problems and symbolic language in mathematics are needed. Since mathematics and science are normally intertwined, these skills are also needed for effective science reading.

Mathematics and Word Problems

Hater, Kane, and Byrne (1974) suggested mathematics materials contain word, symbol, order, and relation in charts, graphs, pictures, and algorithms as well as the normal print. Mathematics symbols have no traditional phoneme-grapheme relationship common to the printed letters and words, therefore the symbols must be committed to the students' sight vocabulary. The mathematics reader must develop sequential eye skills which include more than the traditional left-to-right eye movement, such as combinations of vertical, horizontal, looping, and right-to-left eye movement. Hater, et al. (1974) stated that solving word problems should "include discovering the question, identifying relevant information, translating the information from verbal to symbolic form, using concrete situations to act out problems, recognizing concepts and operations from word forms, and constructing an appropriate mathematical model."

Solving word problems involves integrating most reading skills

unique to mathematics and inherent in science. When word problems are discussed, teachers must consider the decoding act as well as the solving procedure and solution, for the decoding procedure is likely more generalizeable than the solving procedure and definitely more than the solution. The discussion should attend to key words which indicate procedures or attack strategies and sentence forms which generally provide data or request an unknown.

A word problem-solving sequence which will be useful for middle grade students is:

1. Read the problem.
2. Construct a mental or graphic picture of the situation.
3. Consider a series of guiding questions.
   a. What is being asked for?
   b. What data are provided?
   c. What relationship exist between the data provided and the missing data?
   d. Are there any key words which suggest desired action or procedures?

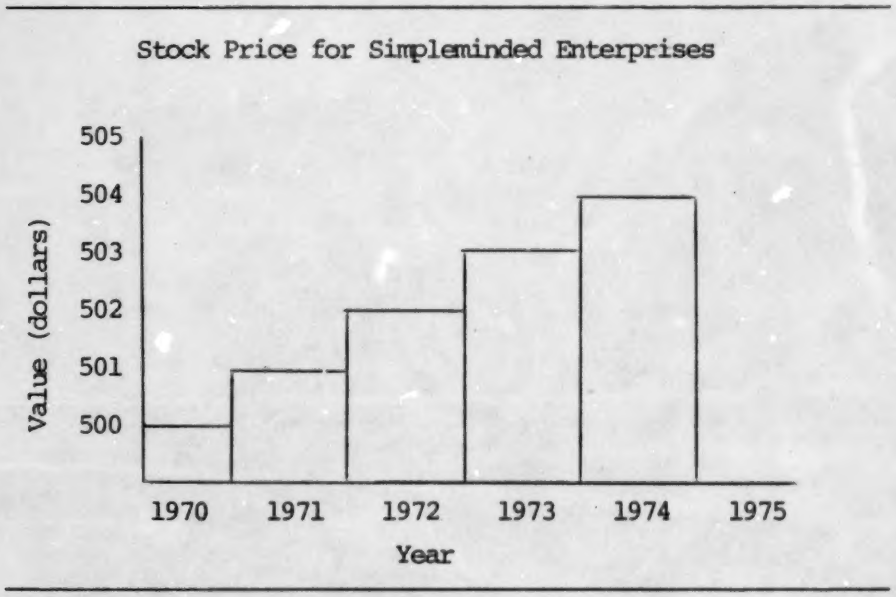
Graphic Materials

Science textual materials and activities also include other reading-like tasks; reading graphs, maps, blueprints, star charts, diagrams, and pictures; and decoding symbolic statements. Reading graphs contains specific pitfalls, and students need to be exposed to these pitfalls under controlled circumstances. The main goal is to have students relate the information in

graphs (and other visuals) to the text. Hater, et al. (1974) indicated that students should: 1) look at the title to determine the nature of the graph, 2) find the main categories used to describe the information contained therein, and 3) identify the details of the chart or graph as they relate to the main categories. Since the horizontal and vertical axes need not use the same scale, students can be confused unless they have previously encountered such situations. Also, since each point on a flat surface represents two pieces of data, students need to have practice with such an experience prior to reading graphs and maps. Games like Battleship (Milton-Bradley) provide children with practice of this prerequisite skill. One of the most common misconceptions in reading graphs results from using non-continuous scales on the horizontal or vertical axes. Figure 4 illustrates a common type of graph related to the mass

Figure 4

Misleading Graphs



media. Notice at first glance it is possible to infer that the growth is greater than it is. Closer investigation and specific consideration of the values on the vertical scale illustrate that the growth, in relative terms, is rather small. Students need to experience this problem to realize the value of checking the scale on the axes before jumping to conclusions.

Science textbooks contain a large amount of flat graphic material in the form of maps, blueprints, and star charts. All of these materials are attempts to represent real space in a non-realistic manner, and special training is needed to develop the appropriate reading skills. Students need to realize that they must attend to ledger, scale, and spatial orientation before much information can be gleaned from the material. Reading contour maps illustrates the unique information that can be obtained from print material. Properly interpreted, the flat print material produces a mental image of a three-dimensional space. The correctness of the image depends on how well the reader decoded the closeness of contour lines and V's in the lines. Mapping Small Places (Wentworth, Couchman, MacBean, and Stecher, 1972) provides excellent activities directed toward these skills.

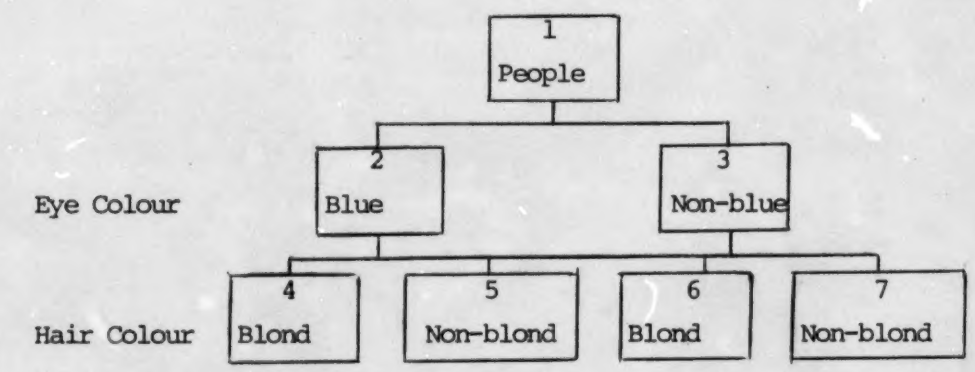
Reading star charts illustrates the spatial orientation problem related with some science materials. Adequate interpretation of star charts requires the reader to vertically and/or horizontally rotate his mental image to correspond with reality. Initially it may be necessary to physically orient the reader in such a way to simplify the spatial translation. This can be done

by having Polaris (North Star) on the star chart pointing north while the reader holds the star chart above his head. Such a physical orientation corrects the directional orientation problem and only requires that the reader linearly extend the charted positions to the approximate real positions.

Reading diagrams in science material is likely an art, not a science for many science illustrators belong in the surrealistic movement. Students must realize that some freedom in interpreting diagrams of arrangements of apparatus and other equipment is possible. Diagrams representing classification keys are simplified once the reader practices developing his own and realizes that reading down the diagram is equivalent to the intersection or compounding of the attributes. Figure 5 illustrates a key for classifying humans by commonly observed attributes. Therefore, any people in space 2 have blue eyes

Figure 5

Classification Key for People



and may have a wide variety of other characteristics, while space 4 is reserved for people with blue eyes and blond hair.

One way of helping students read pictures is to develop the depth concepts of foreground, background and, if possible, middleground. An effective way to develop these concepts is by field-sketching. Students are taken to the area to be sketched, instructed to hold their paper vertically so the area to be sketched appears at the top of the paper, and asked to draw a horizon line near the top of the paper. Students quickly learn that objects near the bottom of the paper are in the foreground, objects near the top of the paper are in the background, while objects near the middle are in the middleground (Cross, 1976). A series of slides of the sketched area illustrating an overview and specific features can serve as a data base for discussion. The location-related questions can be answered by referring to the field sketch. The concepts related to interpreting pictorial data should next be applied to specific cases in science textbooks.

Symbolic Statements

Decoding symbolic statements in science is basically a problem of vocabulary and knowing the meaning of the symbols, such as:

$$\vec{f} = m\,\vec{a}$$

If a student reads the above formula as "f arrow double line m a arrow," it is likely that he does not understand the meaning of the formula. Comprehension is likely better if students are encouraged to read symbolic statements in

terms of their actual meaning, rather than what is printed. Bormuth's (1963) cloze procedure for graphic or symbolic statements supports this practise. Therefore, the short formula found above becomes: "The vector quantity force is equal to the product of the scalar quantity mass times the vector quantity acceleration." This example points out that the readability and length of textual science material cannot be assessed at face value using the number of pages. The teacher must be sure that length of reading assignments reflects the difficulty and variation of materials included.

A final hint to science teachers regarding reading was supplied by Manning (1972) when he noted that the value placed on reading by parents was the major factor affecting the young children's future reading achievement. Rieck (1977) extended Manning's ideas to content teachers and found that most teachers assign reading but their students do not read the assigned material because teachers do not provide purpose or follow-up and are perceived by the students as being indifferent to reading. Rieck believes "teachers who do not read and who do not value reading may pass their limited concept of reading on to their students." Vaughan (1977) has developed a simple scale for assessing teacher attitude toward reading. A first step for the content teachers might be a self-assessment of their attitudes. Second, Rieck (1977) suggested some steps for the content teacher to improve student attitudes toward reading science:

1. Model the reading act.
2. Encourage reading.

3. Share reading materials and ideas.

4. Provide a range of readability and topical materials.

Caution needs to be exerted to use a variety of teaching strategies and learning activities which encourage the development of content, processes, and attitudes that are compatible with the goals of both reading and science.

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